

Contributors

Catherine Chuang, *Lawrence Livermore National Laboratory*

Research Highlight

Previous studies suggest that interactions between dust particles and clouds are significant; yet the conditions where dust particles can serve as cloud condensation nuclei (CCN) are uncertain. Since major dust components are insoluble, the CCN activity of dust strongly depends on the presence of minor components. However, many minor components measured in dust particles are overlooked in cloud modeling studies. Some of these compounds are believed to be products of heterogeneous reactions involving carbonates.

In this study, we calculate Kohler curves (modified for slightly soluble substances) for dust particles containing small amounts of K^+ , Mg^{2+} , or Ca^{2+} compounds to estimate the conditions where reacted and unreacted dust can activate. We also use an adiabatic parcel model to evaluate the influence of dust particles on cloud properties via water competition. Based on their bulk solubilities, K^+ compounds, $MgSO_4 \cdot 7H_2O$, $Mg(NO_3)_2 \cdot 6H_2O$, and $Ca(NO_3)_2 \cdot 4H_2O$ are classified as highly soluble substances, which enable activation of fine dust. Slightly soluble gypsum and $MgSO_4 \cdot 6H_2O$, which may form via heterogeneous reactions involving carbonates, enable activation of particles with diameters between about 0.6 and $2 \mu m$ under some conditions. Dust particles $> 2 \mu m$ often activate regardless of their composition. Only under very specialized conditions does the addition of a dust distribution into a rising parcel containing fine $(NH_4)_2SO_4$ particles significantly reduce the total number of activated particles via water competition. Effects of dust on cloud saturation and droplet number via water competition are generally smaller than those reported previously for sea salt. Large numbers of fine dust CCN can significantly enhance the number of activated particles under certain conditions.

Similarities among Kohler curves for dust containing various highly soluble compounds suggest that these components can be modeled by a single representative substance for most purposes. Also, global aerosol models could benefit by incorporating the dependence of carbonate content on dust source region and particle size, since carbonate content strongly influences dust's water uptake properties. For instance, condensation of H_2SO_4 onto a particle coated with $CaCO_3$ will likely form slightly soluble gypsum until the carbonate is depleted; further H_2SO_4 condensation leads to highly soluble content. Moreover, modeling studies indicate that heterogeneous reactions preferentially occur on fine dust because of the large surface area and long atmospheric lifetime of this mode. However, in regions where carbonates reside primarily in the coarse mode, some reactions could preferentially occur on coarse dust. Improved representations of dust mineralogy and reactions in global aerosol models could improve predictions of the effects of aerosol on climate.

Reference(s)

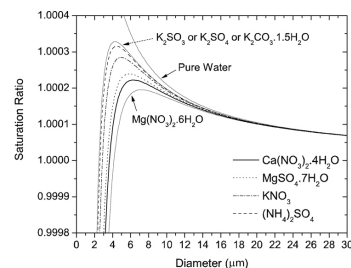


Figure 1. Kohler curves for particles having a $0.79 \mu m$ SiO_2 core coated with highly soluble compounds. Dry diameters for particles with different coatings as follows: $(NH_4)_2SO_4$, $K_2CO_3 \cdot 1.5H_2O$, K_2SO_4 , and $K_2SO_3 = 0.8 \mu m$; $Ca(NO_3)_2 \cdot 4H_2O = 0.82 \mu m$; $Mg(NO_3)_2 \cdot 6H_2O$ and $MgSO_4 \cdot 7H_2O = 0.84 \mu m$.

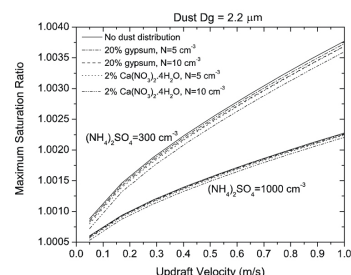


Figure 2. Maximum saturation ratio as a function of updraft velocity for adiabatic parcel simulations having a lognormal $(NH_4)_2SO_4$ distribution ($D_g = 0.16 \mu m$, $\sigma_g = 1.4$) externally mixed with a lognormal dust distribution ($D_g = 2.2 \mu m$, $\sigma_g = 2.0$). Mass percentages of coatings are indicated for dust distributions with the remaining mass as a SiO_2 particle core. Total particle number concentrations are indicated for each distribution.

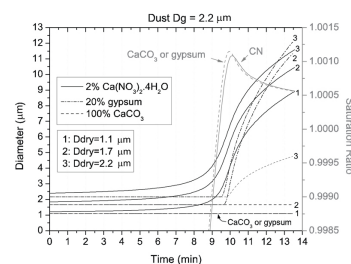


Figure 3. Time evolution of particle diameter and water saturation for simulation conditions of Figure 2 [$(NH_4)_2SO_4 = 300 cm^{-3}$, dust = $5 cm^{-3}$, updraft = $0.1 m s^{-1}$]. Differences in growth occur for particles with the same dry diameter (D_{dry}) but with insoluble ($CaCO_3$), slightly soluble (gypsum), or highly soluble ($Ca(NO_3)_2 \cdot 4H_2O$) components. 'CN' indicates saturation curve corresponding to simulation with dust particles coated by $Ca(NO_3)_2 \cdot 4H_2O$ (2% by mass).

Kelly, J.T., C.C. Chuang, and A.S. Wexler. Influence of dust composition on cloud droplet formation. *Atmospheric Environment* 41(14): 2904-2916 MAY 2007, doi:10.1016/j.atmosenv.2006.12.008.

Working Group(s)
Aerosol

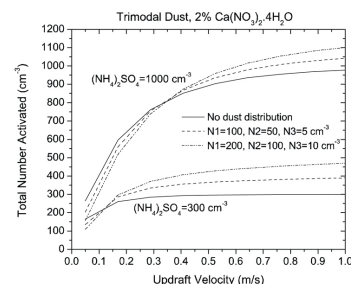


Figure 4. Total number of particles $[(\text{NH}_4)_2\text{SO}_4$ plus dust] that activate as a function of updraft velocity for simulations with an $(\text{NH}_4)_2\text{SO}_4$ distribution ($D_g = 0.16 \mu\text{m}$, $\sigma_g = 1.4$) externally mixed with a trimodal dust distribution containing 2% $\text{Ca}(\text{NO}_3)_2 \cdot 4\text{H}_2\text{O}$ - 98% SiO_2 particles (mass percentages). Trimodal dust parameters are as follows: $D_{g1} = 0.2 \mu\text{m}$, $D_{g2} = 0.8 \mu\text{m}$, $D_{g3} = 2 \mu\text{m}$, $\sigma_{g1} = \sigma_{g2} = \sigma_{g3} = 2.0$ (total number concentrations for modes are given in figure).